JPPT | Quality Improvement

Optimization of Medication Workflows to Improve Timely Medication Administration on a Pediatric Hospital Unit: A Quality Improvement Project

John C. Standish, PharmD; Laura Chapman, PharmD; Ohsha Cloyd, BS; Karan Johnson, RN; Katie Mellody, RN; Karlee Fisher, RN; Cathy Gustavel, BSN; and Michael Bigham, MD

OBJECTIVE Medication workflows are important to improve patient safety and provide timely lifesaving medical care. When operating efficiently, they can also decrease medication and labor waste. The objective of this quality improvement project is to compare missing dose request rates before and after improvements in medication workflows, specifically, decreases in medication and labor waste and the financial implications of these improvements.

METHODS The study evaluated the rate of medication missing dose requests on a 24-bed medical surgical unit in a standalone pediatric hospital from May 2022 to October 2022. Medication workflows were evaluated by pharmacy and nursing team members, and interventions were identified and implemented with the Model for Improvement methodology. Outcomes of missing dose requests per 100 medication doses dispensed were tracked weekly, as were staff time and costs of medications.

RESULTS The missing dose requests per 100 medication doses dispensed decreased from 3.8 to 1.03 during the 6-month initiative. This improvement estimated that 988 missing medication doses were prevented, leading to an estimated $61,038.64 in waste savings. The average cost of the medication and materials (excluding labor) to replace a single missing dose of medication was $61.78. The median cost was $54.71 (IQR, 11.91–4,213.11). Pharmacist, pharmacy technician, and nurse time saved per missing dose were estimated to be 6, 14, and 17 minutes, respectively.

CONCLUSION Multimodal improvements in inpatient medication workflow reduce missed medication errors and improve cost and labor efficiencies.

ABBREVIATIONS ADC, automated dispensing cabinet; EHR, electronic health record; IV, intravenous; PDSA, plan-do-study-act

KEYWORDS medical waste; medication waste; patient safety; pediatric pharmacy; pharmacy practice; quality improvement

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Introduction

Medication errors are a common source of pediatric health care harm. Per the US Pharmacopeia, pediatric patients experience significantly more medication errors than adult patients (31% vs 13%, respectively).[1] It has been estimated that in the United States, 7.5 million preventable pediatric medication errors occur each year.[2] Literature has shown that 0.24% of medication errors in pediatric patients lead to harm, including 7000 patient deaths annually.[2,3] This increased risk of harm is due to the lack of available pediatric dosage forms (e.g., oral liquid suspensions, solid dosage forms in appropriate dosages)—the standard for weight-based dosing in pediatric patients—and the need to use nonstandard dosages to ensure pediatric patients can receive the medication at the proper dose.

Medication errors for hospitalized children result from failure of 1 or more of the 5 key steps in the medication pathway: ordering, transcribing, dispensing, administering, and monitoring. Patient-specific doses are prepared in hospital pharmacies and delivered to inpatient units. Once these doses are delivered to inpatient units, they are subsequently administered by a nurse at their ordered administration time. This process falters when the nurse cannot locate these doses to administer to the patient, which results in system inefficiency. These inefficiencies include medication waste, lost labor from attempts by pharmacy and nursing to locate the dose, compounding a new dose, and

delivering the new dose. In addition to these sources of waste, delays in patient care also result from the medication being unavailable to administer when needed. Untimely administration of medication can cause direct harm to pediatric patients.[4] Furthermore, the time and energy invested in locating a missing medication dose or re-preparing it can result in time away from other patient care needs, indirectly contributing to additional patient harm.[5]

Internal baseline data showed that 3.8% of the medications dispensed by pharmacy are reported missing (3.8 missing medication requests per 100 doses dispensed). If nursing cannot find the medication when they are scheduled to administer it, they will contact pharmacy by phone or by the *medication message* function within the Epic electronic health record (EHR) (Verona, WI). Pharmacy staff will confirm the location of the medication or prepare an additional dose of medication and deliver it for administration.

This quality improvement study compared missing dose requests per 100 medication dispenses pre and post intervention to enhance the efficiency in the medication dispensing and administration domains. The goal of this initiative was to reduce missing dose request dispenses on a single multispecialty medical/surgical inpatient unit and quantify the efficiency improvements achieved in both time and costs.

Methods

Setting. This study was conducted at a large freestanding quaternary children's hospital system in the Midwestern United States with more than 440 inpatient beds. The inpatient pharmacy dispenses at least 30,000 inpatient medication doses to inpatient units per month. These doses are primarily patient-specific enteral liquid and intravenous (IV) medications. Pharmacy staff transport these doses to inpatient units by hand or via a pneumatic tube system. A 24-bed medical surgical unit, serving primarily adolescent children, was selected to evaluate the missing medication dispense rate and contributing causes. The patient to nurse ratio on this unit is on average 5:1. The improvement project spanned from May 2022 to November 2022 with subsequent sustainability monitoring through July 2023.

The pharmacy department standardly delivers medications by hand directly to the unit medication room at prespecified times where they are stocked in a patient-specific bin or in an automated dispensing cabinet (ADC) (Omnicell, Mountain View, CA) for general access for commonly administered medications. The first dose following the verification of a new medication order is typically delivered via our pneumatic tube system. Controlled substances and hazardous medications cannot be delivered via the pneumatic tube system per policy and are delivered by hand. Prior to this project, there was no standard process in place for pharmacy and nursing to locate medications that were not available on the unit.

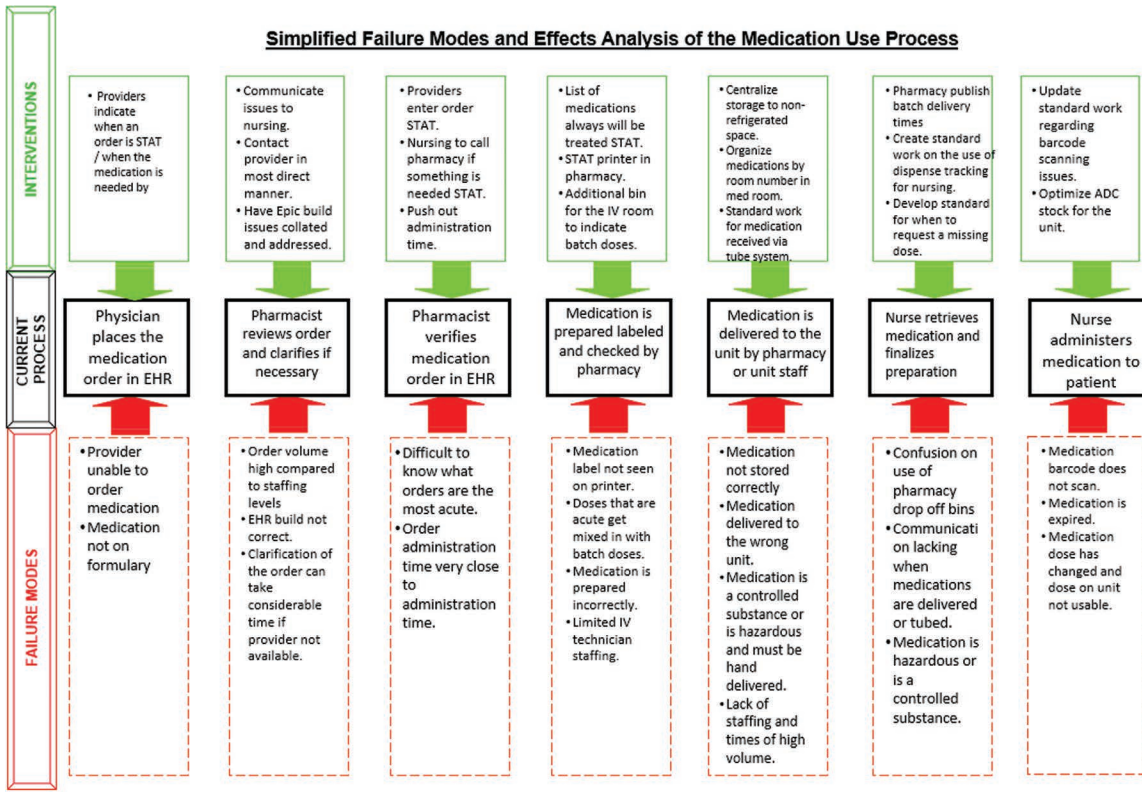
Quality Improvement Overview. This improvement project was completed by using the Model for Improvement methodology.[6] A multidisciplinary team was created that included 3 clinical care nurses, a nurse educator, a respiratory therapist, a unit secretary, and 2 pharmacists. *Ad hoc* input from resident physicians was included to assist with understanding parts of their workflow that affect medication order verification. Key improvement tools included a key driver diagram, process mapping, U charts, Pareto charts, simplified failure modes and effects analysis (Figure 1), and plan-do-study-act (PDSA) cycle testing.

Intervention Development. An analysis of the missing dose requests from the previous 6 months to see which medications, dispense types, delivery locations, and delivery methods had the most missing dose requests was completed to assist in identifying types of medication dispenses most associated with a missing dose request. Baseline missing dose request dispenses were established by averaging the missing dose request dispenses from March and April 2022. A key driver diagram (Figure 2) was created from the simplified failure modes and effects analysis, and missing dose analysis was developed to highlight key drivers and potential interventions to focus improvement efforts. Five key drivers were prioritized by a simple majority of the multidisciplinary improvement team; they informed the intervention development and were tested in a PDSA fashion: 1) improve communication between pharmacy, nursing, and ordering providers; 2) increase awareness of where medications are stored; 3) optimize ADC inventory; 4) increase time to prepare and administer the drug by the assigned administration time; and 5) streamline order entry process to indicate when a medication is needed.

To improve communication between pharmacy, nursing, and order providers, a set of clear and precise standard ordering instructions were developed for the use of dispense tracking technology within the EHR (see Supplemental Table S1), and for the process pharmacists should use to communicate with providers to clarify medication orders in question. Standard work instructions for the use of dispense tracking technology allowed nurses to be trained on how to use this technology to see where in the dispensing process the medication was, if it was delivered, and how it was delivered. This information was previously found through phone calls or messages in the Epic EHR, or not available at all.

To improve awareness of where medications were stored, standard work instructions were developed to guide handling of medications delivered through the pneumatic tube system (see Supplemental Table S2). Previously, doses of medications were taken from the pneumatic tube system to a variety of final delivery

Figure 1. Simplified failure modes and effects analysis.



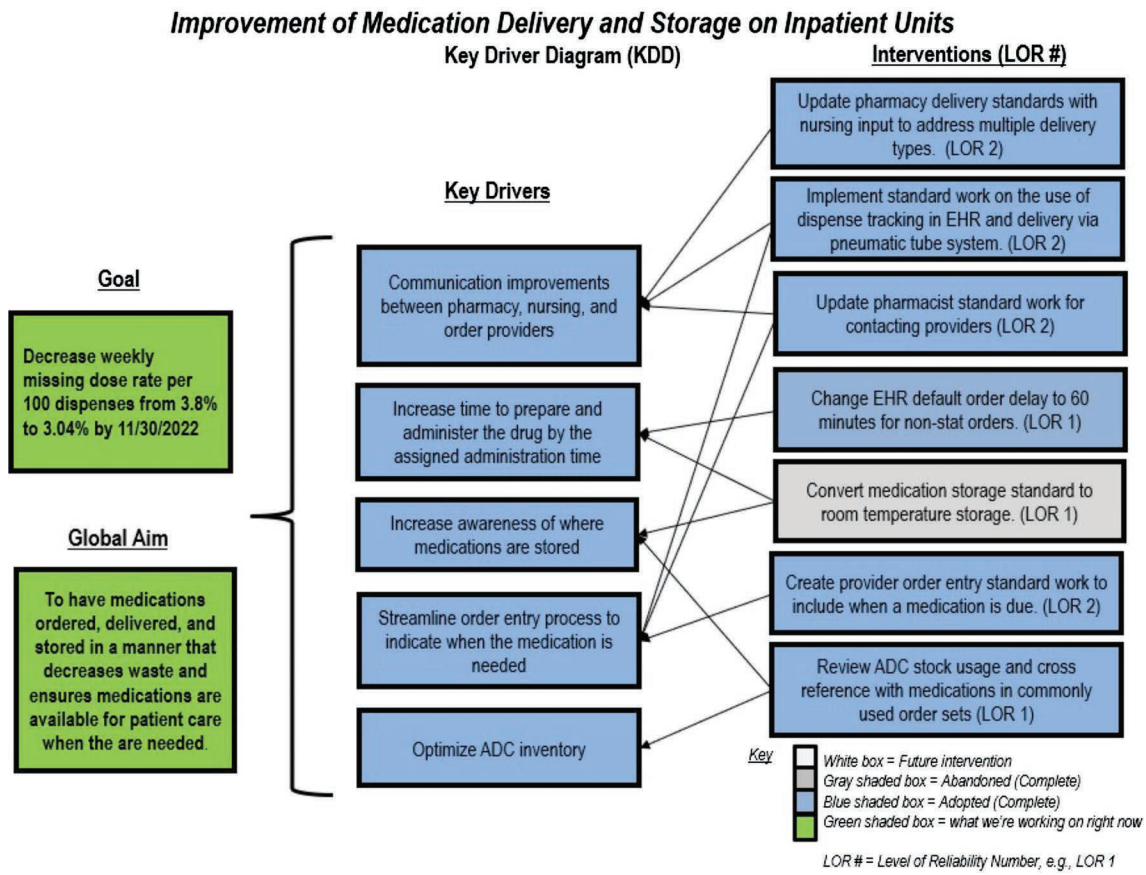
ADC, automated dispensing cabinet; EHR, electronic health record; IV, intravenous

locations, making the dose difficult to locate. The new process requires that all doses of medication delivered through the pneumatic tube system be taken to the unit medication room to decrease resources used in looking for the medication. The 2 interventions combined were designed to make it clear where medications were located.

Optimizing the inventory in the ADC on the unit was also identified as a critical intervention, based on the review of all missing dose requests that identified what medications, dispense types (e.g., sterile products, oral liquids, unit dose tablets), delivery locations (e.g., room temperature storage, refrigerated storage, ADCs), and delivery methods (hand delivered vs pneumatic tube system) were most frequently missing. Most missing medications were not stored in the ADC, were frequently used medications, medications from commonly used order sets, or medications stocked in the ADC that had insufficient inventory based on usage. The pharmacy team revised the inventory in the ADC to match usage of identified medications.

Optimization of the EHR medication order process increased time to prepare and administer the drug by the assigned administration time and streamlined the order entry process to indicate when a medication is needed. The team identified the following areas for improvement: 1) medication order default start times are too close to the time of order verification to allow the pharmacy time to prepare and deliver the medication; 2) nursing is required to administer a dose of medication within an hour before or after the scheduled due time, leading to urgency to acquire the medication; and 3) pharmacy is rarely aware of when medication orders are needed immediately, owing to the lack of provider notification during medication order entry. The Information Services team facilitated EHR build improvements by modifying the default medication start time interval in the EHR. The default medication start time interval at discovery was to round up the administration time to the next 30-minute interval but was revised to round up to the next 60-minute interval. This allowed pharmacy adequate time to verify the medication order, prepare the medication, and deliver it to the unit before the dose is needed by nursing. The next intervention was to address streamlining of the order entry process to indicate when a dose is needed. The team discovered an ordering provider knowledge gap in their ability to change the start time for that order, indicate the order was needed

Figure 2. Key driver diagram.



ADC, automated dispensing cabinet; EHR, electronic health record

urgently, or see when the first administration would be due while entering the order. With the help of the resident physicians (common ordering providers), we were able to develop education on how to recognize and change the start time of an order and indicate if it was needed urgently during order entry. By knowing when the medication is needed, pharmacy can better prioritize which medication order should be verified and dispensed first.

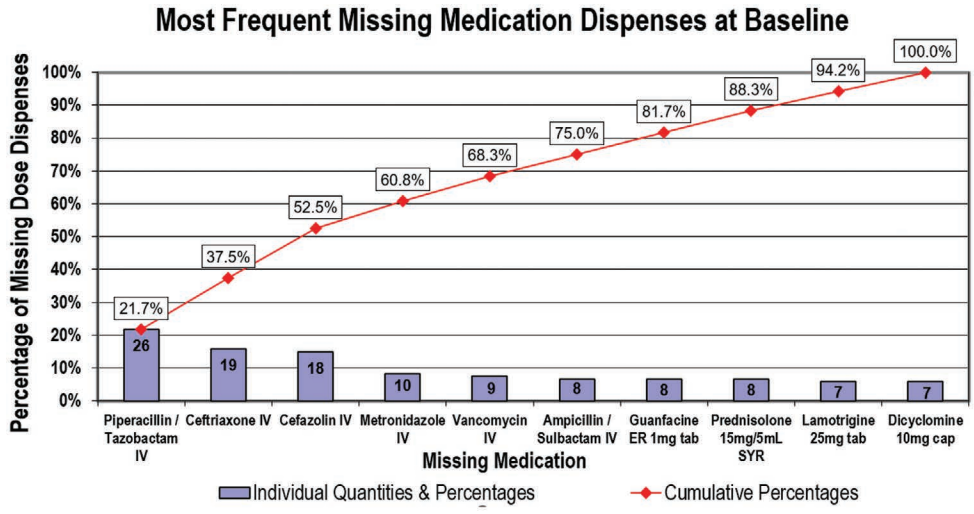
Measurements and Reporting. The primary measure was missing medication dose request rate per 100 medication doses dispensed. The data were collected prospectively from May 2022 through November 2022 by the primary investigator (JCS). These data were measured weekly by quantifying all electronic missing dose requests dispensed divided by the total number of medication doses dispensed. These data were acquired though EHR reporting. Descriptive statistics were used to describe quantitative and percentage change in the missing dose rate per 100 doses dispensed from baseline, average costs, average time expenditures, and median values of medication costs. The secondary measures captured included nursing and pharmacy time spent addressing missing dose requests and the amount of medication waste, in dollars, that was accumulated from having to re-dispense a medication. This was measured by observing 100 missing dose request medication dispenses. The time measured from these 100 observations was averaged. To quantify the total amount of time spent, this average time was multiplied by the total number of missing medication doses dispensed. Drug waste was averaged in a similar fashion over these 100 dispenses to establish an average medication cost per missing dose request dispense. Final accumulations of time and medication waste were based on the percentage decrease of missing dose request dispenses from baseline at the final weekly measurement prior to November 30, 2022. A balancing measure documented was the total quantity of expired medications retrieved from the unit ADC to monitor for an increase in expired medications due to an increase in medication inventory in our ADC machines.

Results

Baseline measurement of the primary outcome was 3.8 missing medication dose request dispenses per 100 medication doses dispensed. The Pareto charts for the most frequently missing medications are outlined in Figures 3 and 4. The most frequent missing dose requests were for first-dose IV antibiotics that were dispensed from pharmacy. When excluding first-dose IV antibiotics, the next most frequent category was oral unit dose medications that were included in commonly used order sets on the unit and were not stocked in the ADC.

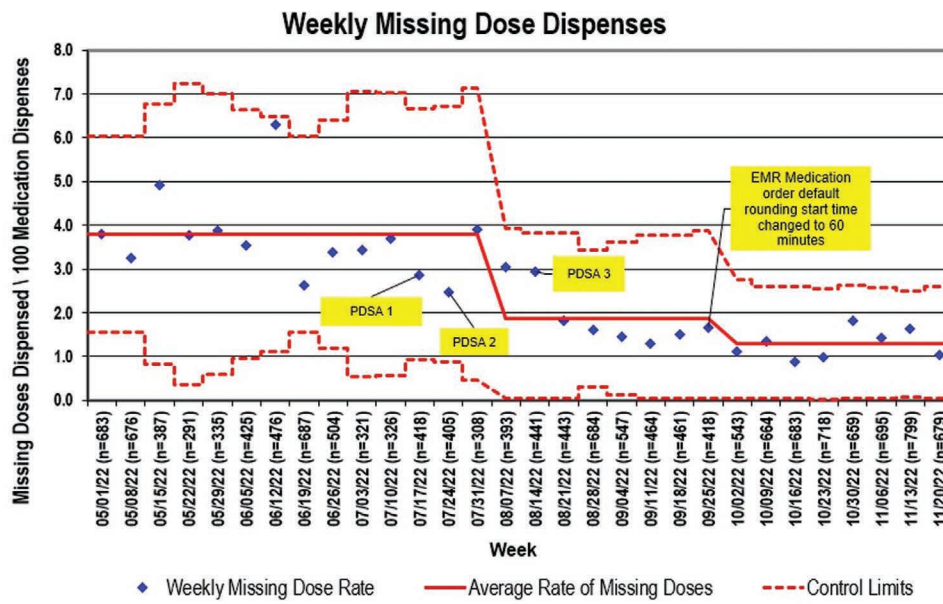
The primary measure of missing medication dose requests dispenses per 100 medication doses dispensed decreased from a baseline of 3.8/100 (3.8%) to 1.03/100 (1.03%) (Figure 5). This marked a decrease of 271% in missing dose request dispenses from baseline from

Figure 3. Pareto chart—most frequently missing medications at baseline.



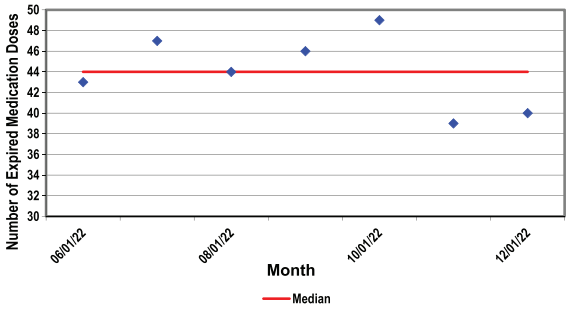
cap, capsule; ER, extended release; IV, intravenous; SYR, oral syringe; tab, tablet

Figure 4. U chart—weekly missing medication dose dispenses per 100 medication doses dispensed.



EMR, electronic medication record; PDSA, plan-do-study-act

Figure 5. Monthly total of medications wasted from ADC machines.



ADC, automated dispensing cabinet

May 2022 through November 2022. This resulted in 19 total weekly missing medication doses avoided following implementation of all interventions. The secondary outcome of time and medication waste savings can be seen in the Table. Based on 100 direct observations, the measured time for each missing dose request medication dispense resulted in a loss of 6 minutes of pharmacist time, 14 minutes of pharmacy technician time, and 17 minutes of nursing time. The average cost of the medication and materials (excluding labor) to replace a single missing dose of medication was $61.78. The median cost was $54.71 (IQR, 11.91–4213.11). With our improvement from baseline, this would equate to an annual cost savings of $61,038.64 based on the average cost to replace a single missing dose. The balancing measure of the quantity of expired medications retrieved from the unit ADC was no different from baseline through the completion of this project. This was measured to see if there was an increase in expired medications due to increased medication inventory being stored in the ADC.

Table. Labor and Pharmaceutical Waste Savings

Labor Savings		
Role	**Time Spent Per Missing Dose, min**	**Estimated Annual Labor Time Savings, min**
Pharmacist	6	5928
Pharmacy technician	14	13,832
Nurse	17	16,796
Pharmaceutical Waste Savings		
Medication Cost Per Missing Dose	**Missing Doses Prevented**	**Estimated Annual Pharmaceutical Waste Savings**
$61.78	988	$61,038.64

Discussion

Other studies and review articles have investigated reducing missing medications and waste. These studies primarily focused on internal pharmacy workflow optimization[7–9] use of computer model estimates or simulations,[7,10,11] and/or implementation of technology.[11,12] In contrast, this study prospectively evaluated missing dose data by a multidisciplinary team that focused on workflows that carried across disciplines in addition to internal workflows. All members of the team evaluated the workflow from start to finish to identify areas that affect the rate of missing doses along with medication and labor wastes.

Our primary outcome showed a better-than-expected decrease in missing dose requests per 100 doses dispensed from 3.8 to 1.03, a 271% improvement. Pharmacist, pharmacy technician, and nursing labor time saved, based on this decrease, was 6, 14, and 17 minutes, per dose, respectively. There was no difference in medication waste from the unit ADC following changes to its medication inventory. Efficiency and cost saving can be realized with focused improvement efforts.

This project addresses both financial and operational efficiency. With health care systems across the country pressured to find ways to optimize efficiency of current resources and reduce waste, this is an example of how both objectives can be achieved. This project occurred on just 1 inpatient unit and yielded 100 minutes of staff time per shift. If this were spread to all patient care areas, the impact could be even greater across a health care system. To achieve this time efficiency, the most significant intervention was aligning drugs included in commonly used order sets with the medication inventory in ADC cabinets. Inventory optimization did not cover all medications ordered. When the standard start time for medication orders was extended to 60 minutes, this helped give the pharmacy time to prepare and deliver the medications not in the ADC and allowed nursing to give the medications at their ordered due time. These 2 interventions in combination appeared to have a synergistic effect on decreasing the missed medication requests. A surprising finding was the average cost of the medication doses that were re-dispensed ($61.78/dose). Pharmaceutical expenditures have been increasing rapidly during the past 20 years, largely due to the increased cost of new and current therapies.[13] With medications becoming more costly, the expected average cost per dose was anticipated to be higher. However, the frequency of missed dosing requests with re-dispensing demonstrates that even at $61.78/dose, the aggregate financial impact of avoiding re-dispensing is material ($61,038.16 estimated annual savings). These interventions on inpatient care areas that administer more high-cost medications would produce a larger financial savings.

These results show that improvement in the medication ordering, preparing, and administration workflow

can significantly affect quality and safety. Optimizing patient care is also core to the mission for all health care systems. Medication delays threaten optimal care, as evidenced by the designation of medication delays as a National Patient Safety Agency goal.[14] Not only does timely medication delivery improve care, but also nursing distraction can negatively affect patient safety.[15,16] The hunt for missing medications and the time consumed negotiating and receiving a new medication are indisputable distractions. Pharmacists are also affected by these distractions, leading to increased errors.[17,18]

One of the most beneficial learnings from this improvement project is the newfound understanding and knowledge regarding interdepartmental workflows. Prior to this multidisciplinary improvement team formation, many assumptions about how pharmacy and nursing workflows functioned were not accurate. A key strategy to understand the workflows was observation on the clinical units and in the pharmacy. Through these observations, the assumptions regarding pharmacy and nursing workflows were proven inaccurate, allowing for collaboration and improvements to be made. Many improvement projects can succeed through small team or secular improvement, but this project demonstrates the necessity and value of cross-functioning teams to identify and drive improvement interventions. Physical observation or "Gemba walks" have been shown to provide a better understanding of workflows and allow those in the workflow to help identify and solve problems.[19] This allowed our team to gain knowledge on the issues affecting the groups outside of their professional discipline and communicate better across disciplines.[20]

With the improvements we made in reducing missing dose requests, medication waste, and labor waste, we also identified other ways for improvement. First, we did not evaluate our daily batch schedule within the pharmacy. Deliveries that occur close to common administration times can increase missing dose requests because of the limited time between medication delivery and medication administration. Increasing the number of batches you complete a day can decrease waste by preventing doses from being made that were either discontinued or are meant for a discharged patient, but it also increases the labor needed to deliver the additional batch doses to patient care units. Second, education of new employees on the updated medication workflows needs to occur to maintain these results. We have identified that including a medication workflow section into new employee onboarding is vital to continue this success. Third, this study was conducted on a single inpatient medical surgical unit. The opportunity to spread these improvements to other units will greatly decrease missing medication requests, medication waste, and labor waste across the whole health system.

There are several limitations to this study. First, this is a local study at a standalone children's hospital focused on an individual unit. Adult or pediatric systems still should be able to apply the process used in this study, but their individual interventions and impacts may be different. Second, this project took place in a medical surgical unit, whereas an intensive care unit or emergency department may have different needs. These interventions will need to be validated in these patient care areas. The interventions may also have a larger impact on a unit that has higher-cost medications. Third, while the team did calculate the time saved from distractions from missing doses, there was no measurement of what was done with the time saved. Fourth, this study involved solely pediatric patients. This may underestimate the impact of a similar quality improvement initiative at an adult center where standard dosage forms are much more common and are more easily dispensed from an ADC. Fifth, the balancing measure of waste from ADC-stocked medications is a lagging indicator because it will take time for medications to expire. However, new medications added were used frequently and thus should be used well ahead of expiration. Additionally, there are other strategies in place to improve prioritization and efficiency of medication dispensing (e.g., STAT bins, label indicators). Staffing was deemed adequate for both pharmacy and nursing during this period.

Conclusions

This improvement study demonstrates a multidisciplinary team's successful reduction in missed medication dosing requests with a measurable impact on efficiency and waste reduction. Keys to this successful improvement included medication dispensing and delivery standard work establishment, medication standardization in the ADC, and use of EHR constraints around medication order to administration times. Future work will allow local system-wide spread, though this could represent a substantial improvement opportunity for many health care institutions.

Article Information

Affiliations. Department of Pharmacy (JCS, OC), Akron Children's Hospital, Nursing (KJ, KM, KF), Akron Children's Hospital, Quality (CG, MB), Akron Children's Hospital, Akron, OH; Department of Pharmacy (LC), Cleveland Clinic Children's Hospital, Cleveland, OH.

Correspondence. John C. Standish, PharmD, MBA; jstandish@akronchildrens.org

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Ethical Approval and Informed Consent. This study was classified as quality improvement, nonhuman research and was approved by the appropriate committees at our institution.

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